Oceanography Committee

ICES CM 2002/C:05
Ref. ACME, ACE

Report of the

Workshop on Contrasting Approaches to Understanding Eutrophication Effects on Phytoplankton

The Hague, The Netherlands
11–13 March 2002

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark

TABLE OF CONTENTS

1 BACKGROUND TO THE WORKSHOP

The ICES Working Group on Phytoplankton Ecology (WGPE), at its annual meeting in March 2001 in Bergen, Norway proposed that a Workshop on the impacts of nutrient enrichment on phytoplankton behaviour in coastal waters and inland seas be convened in 2002. This recommendation was in response to a Term of Reference to "*prepare a draft resolution for a Workshop on the role of anthropogenic forcing in planktonic ecosystem change to be carried out in 2002*". WGPE formally recommended this action as a draft resolution in its annual report to ICES (ICES CM 2001/C:08), with the following provisions: that WGPE will prepare for a Workshop having the provisional title *Contrasting approaches to understanding responses to nutrient enrichment; the mass balance versus the organism approach*; that the Workshop will be convened in the The Hague, Netherlands, in March 2002, and it would be co-Chaired by T. Smayda, P. Bot and D. Mills. WGPE made this recommendation because of the increasing number of Terms of Reference that it was being asked by ICES to advise upon, and the conclusion of WGPE members that their future deliberations on eutrophication related matters would benefit by convening a workshop of experts on this issue.

Following endorsement of the Workshop Resolution (C.Res 2001/2C05) at the 89th ICES Statutory Meeting, the organization of the Workshop was initiated in earnest in September 2001 by Drs. Smayda, Bot and Mills together with Dr Edler. Drs. Mills and Edler met in London in October, and again with Dr Smayda in Texel, The Netherlands, in early November, joined there also by Dr Bot. Drs. Mills and Bot also met in The Hague in October. It was agreed that the Workshop title would be *Contrasting Approaches to Understanding Eutrophication Effects on Phytoplankton*. At the Texel meeting, an invitation list was drawn up, and invitations sent by e-mail, primarily by Dr Smayda and Dr Mills; Dr Edler contacted some Scandinavian invitees. This was followed up by formal invitations sent by Dr Bot, whose office coordinated responses in preparing for the logistical needs of the meeting.

The following report summarises the organizational procedures for the Workshop, its content, and its highly successful outcome.

2 WORKSHOP WEBSITE

Under the supervision of Dr Mills, the Workshop website (http://www.cefas.co.uk/eutwork/default.htm), was set up on the homepage of CEFAS (The Centre for Environment, Fisheries & Aquatic Science), Lowestoft Laboratory, Lowestoft, UK. The website (Appendix 1) included the Workshop Programme and Speakers (Appendix 2); Abstracts of the presentations (Appendix 3), and travel and accommodation information. The website is being maintained as a bulletin board for subsequent Workshop activities, including information pertinent to publication of the Workshop proceedings.

3 SELECTION OF SPEAKERS AND OTHER PARTICIPANTS; FUNDING

The organizing committee recognized that if the Workshop was to be successful, the scientists to be invited should be actively involved in the "eutrophication" issues to be discussed. It was also decided that the invitees should not be restricted to the ICES region: the issue transcends regional considerations; it involves ecosystem change occurring at basic levels; and the signals and intensity of response of the phytoplankton to altered nutrient levels in coastal waters vary globally as a function of the severity of nutrient loading. A comparative ecological analysis was needed. These features required a mix of scientists experienced in these areas, which led to another Workshop decision: the Programme (Appendix 2) was to consist of four main elements: Case Histories, Driving Forces, Ecophysiological Aspects of Nutrients, and Mass Balance and Modelling Approaches to the "eutrophication" problem. From this combination of presentations, it was hoped that the Workshop would indeed provide new perspectives into the effects of altered nutrification on coastal phytoplankton communities, and into investigative procedures.

Scientists having these selection criteria were invited to participate in one of three Workshop categories: as a Keynote speaker; as a Speaker, or as a Participant. A sample Letter of Invitation is found in Appendix 4. In all, 32 (of 45) invitees accepted their invitations, representing 17 countries and geopolitical subdivisions: Belgium, Bulgaria, China, Croatia, England, France, Germany, Greece, Japan, Netherlands, Northern Ireland, Norway, Korea, Scotland, Sweden, Wales, U.S. Most of the top scientists working on Workshop issues attended.

Of the nine ICES nominated delegates to the Workshop, six attended (Drs. Franciscus Colijn (Germany), Philippe Cugier (France), Lars Føyn (Norway), K.J. Hesse (Germany) and T. Smayda (U.S.). Dr Cugier submitted an Abstract, which was accepted for presentation. In total, 44 individuals attended the Workshop, as identified in Appendix 5.

Excluding Workshop conveners, Drs. Smayda, Mills, Bot and Edler, the Workshop provided all of the non-European invitees their travel and accommodation costs and a daily subsistence, as outlined in the letters of invitation (Appendix 4). European investigators were also provided funding in many instances, with the level of support varying with their need. Workshop funds were obtained through the efforts of Dr Bot and Dr Mills, and without which the Workshop could not have been organized and convened in the format used. The tremendous contributions of Dr Bot, Dr Mills and their institutions, Rijksinstituut voor Kust en Zee (RIKZ), The Hague, and The Centre for Environment, Fisheries & Aquatic Science (CEFAS), Lowestoft, UK, respectively, cannot be exaggerated. In addition to arranging for financial support, Dr Bot and RIKZ provided key logistical support, made available at no charge the excellent facilities at RIKZ, and provided luncheon and coffee break refreshment *gratis* to Workshop attendees. A letter of thanks was sent to Dr Ir. M. A.M. Beljaars, Director of RIKZ. Dr Mills and CEFAS assumed the cost of setting up and maintaining the Workshop website (EutWork).

4 PROGRAMME: SCIENTIFIC PRESENTATIONS

The Workshop began on Monday, 11 March, starting off with a welcoming address delivered by Dr Ir. R. Papenhuizen, Chief of Information and Technology, RIKZ, followed by introductory comments by Dr Smayda on Workshop organization its objectives, and by Dr Bot on logistical matters. The ensuing programme consisted of 33 presentations, including three Keynote addresses (Appendix 2). Following a Keynote address by Prof. Dr Eystein Paasche, Univ. of Oslo, giving an historical perspective on changing insights and approaches to the issue of nutrients and phytoplankton growth *in situ*, Dr Stephen Malcolm, of CEFAS, discussed the societal issues involved in dealing with eutrophication of coastal waters from the perspective of regulatory and advisory bodies, such as the European Commission and OSPAR. Case histories on the relationship between eutrophication and altered phytoplankton behaviour, or responses to nutrients, were then reported for Chinese, Japanese and Korean coastal waters; for the Black Sea, Aegean Sea, Kastela Bay (Adriatic Sea); for the Baltic Sea, Kattegat, Skagerrak, Dutch Wadden Sea; the southern North Sea, Irish Sea, and Delaware Bay, USA

The session on Driving Forces on day two considered the confounding effects of climate change and eutrophication in modifying phytoplankton dynamics; the role of freshwater delivery of nutrients, and how variations in riverine delivery of nutrients and changes in nutrient ratios have upper trophic level effects which can reversibly influence phytoplankton behaviour through “top-down” control. The programme then considered ecophysiological responses of the phytoplankton at cellular and species levels in laboratory and natural systems, and theoretically, following a Keynote address by Prof. Dr Paul Tett, Napier University, Edinburgh, Scotland, on eutrophication as a process in which nutrient levels, ratios and grazing are important factors. This session on Physiology and Nutrients was followed by a Keynote lecture by Prof. Dr Ted Smayda, University of Rhode Island, U.S., on the need to apply species-based approaches when investigating potential linkages between nutrient increases and altered phytoplankton behaviour, particularly given the inadequacy of the biomass (= mass balance) approach traditionally applied. The differing definitions of eutrophication and variable indices of eutrophication currently being applied in managerial situations were also discussed, and the need to standardize criteria pointed out.

Subsequent issues dealt with in the session on Mass Balance and Modelling on day three focused on the need for, and different approaches to modelling eutrophication and its effects on phytoplankton. The modelling of harmful blooms, individual species, functional groups (diatoms vs. flagellates), and the AMORE (Advanced Modelling and Research on Eutrophication), ERSEM (European Regional Seas Ecosystem Model) and NORWECOM models were considered in this final Workshop session.

5 PLENARY SESSION

A Plenary Session was convened on the final day of the Workshop for general discussion of the scientific presentations. The objective was to seek, if possible, a plenary consensus with regard to current knowledge on the relationship between nutrification of coastal waters and phytoplankton responses, and the research needed to quantify this relationship. The intent was to submit this plenary resolution as a Workshop product for publication in a journal such as Marine Pollution Bulletin or Ambio for further use and consideration by the scientific and regulatory agency communities at large. It was also intended for internal use by ICES, particularly in connection with its various liaisons with regulatory and advisory bodies, such as OSPAR. Prof. Dr Franciscus Colijn, Kiel University, chaired the Plenary Session.

Dr Paul Harrison, Hong Kong University of Science and Technology, was invited to serve as a synthesizer of the Workshop presentations, and his overview began the plenary discussion. Workshop attendees were then asked to select three (they selected four) of the following ten topics for detailed plenary discussion.

1) Is there evidence that nutrient enrichment of coastal waters is leading to altered phytoplankton dynamics?
2) If yes, have adverse ecosystem responses accompanied this nutrification? if yes, what are the symptoms?

3) Are these adverse responses generic, e.g., extrapolatable as first principles, or primarily site-specific consequences of narrower interest?
4) Can nutrification effects on phytoplankton be modelled, with fidelity, for mass balance, species-specific and functional group behaviour?
5) Do available models have predictive capacity?
6) Can eutrophication processes and impacts be adequately quantified applying approaches which focus on:
    a) Habitat quality
    b) Mass balance
    c) Species-specific measurements?
7) What knowledge and technical gaps are impeding progress towards quantification of nutrient enrichment impacts on phytoplankton?
8) Can meaningful i*n situ* experiments be carried out relevant to eutrophication?
9) How would you define eutrophication?
10) Is the practise of regulatory agencies to focus on nutrients and phytoplankton as measures of realized and potential effects of eutrophication appropriate, or should some other tropic or habitat component(s) be the focus?

It was generally acknowledged that all questions were worthy of discussion, but time constraints did not allow this.

Topics 1, 3, 4 and 7 were selected for discussion by majority vote of Workshop participants; much discussion followed, as summarized below.

#1. Is there evidence that nutrient enrichment of coastal waters is leading to altered phytoplankton dynamics?

Discussion first centred on the meaning of the terms nutrient enrichment and dynamics, and resulted in the revised inquiry:

> **Is there evidence that anthropogenic nutrient supply of coastal waters is leading to altered phytoplankton dynamics and/or communities?**

The consensus was that this was generally the case, with supporting evidence available in the Case Histories presented at the Workshop. In general, an increase in nutrients leads to increases in biomass (chlorophyll) and primary production. With regard to changes in species composition and the selection of erstwhile "good" vs. "bad" species (functional groups), the evidence is mixed. It was emphasized that an adequate time series, including baseline data, is needed to distinguish between the effects of nutrient oversupply and natural variance. Experimental confirmation of purported eutrophication - phytoplankton responses is also needed, but recognized to be difficult to acquire for methodological reasons and difficulty in achieving relevant simulations of ecosystem structure and processes.

 # 3. Are these adverse responses generic, e.g., extrapolatable as first principles, or primarily site-specific consequences of narrower interest?

Discussion of this question was intense, with interest in how to interpret the term "generic", i.e., the notion that since a dose-yield relationship occurs between nutrient supply and phytoplankton biomass and primary production levels, then it can be expected that at sites where increases in nutrients occur, an increase in biomass and primary production will result (i.e., the "first principle" extrapolation). With regard to the site-specific reference in the inquiry, it connotes that locally observed responses can not be generally extrapolated. It was agreed that in order to assess these prospects, there is need to distinguish between mass balance responses and species-specific responses, and to recognize that these responses are non-linear, which obscures the enhanced nutrient supply-phytoplankton response relationship.

With these clarifications, the Workshop consensus was that while the underlying factors (mechanisms) and ecological principles apply universally, the outcome of the collective phytoplankton response to nutrient loading is often site-specific. Within this behaviour, the majority view was that the mass balance and functional group responses were more likely to conform to expectation than predictions of species level responses, which are often erratic. Therefore, the Workshop conclusion with regard to the "first principles" portion of the inquiry (#3) is that it is appropriate "to some extent", with a much lower degree of confidence for predicting species level responses than for mass balance responses. With regard to the site-specific issue: the Workshop majority opinion was that the underlying, first principle factors are not violated at specific sites. However, at these sites local habitat conditions, which include a multiple of physical, chemical and biological factor interactions can obscure the role of altered nutrient levels on phytoplankton behaviour.

This compromises the regional extrapolation of species-specific behaviours observed at one site to expected behaviour in another habitat at similar stages of nutrient enrichment.

 # 4. Can nutrification effects on phytoplankton be modelled, with fidelity, for mass balance, species-specific and functional group behaviour?

Workshop participants agreed that this inquiry needed restatement and qualification, and since models are developed for different applications, the required rigour and fidelity of the model will vary with the intended use of the model. Since by this stage in the Plenary Session the need to distinguish between mass balance, functional group and species level responses was recognized, they were incorporated into the inquiry. Acknowledging that there are various types, classes and applications of models, Workshop participants rephrased the question to read:

> **Can reliable (useful) models be made for the effects of nutrification on phytoplankton mass balance, species-specific and functional group behaviour?**

In this restatement, the term "fidelity" was deleted, since fidelity implies predictive power, a capability which Workshop attendees agreed was limited, if at all attainable, based on current knowledge on the nutrient enrichment - altered phytoplankton behaviour relationship. With this proviso, it was concluded that useful models of the mass balance type are available to managers.

#7. What knowledge and technical gaps are impeding progress towards quantification of nutrient enrichment impacts on phytoplankton?

This question elicited considerable discussion, and demonstrated the great value of convening an interdisciplinary Workshop of biologists, chemists, physical oceanographers and modellers, a particular strength of WKNUPE. The need for interdisciplinary collaboration was emphasized, with dialogue on "what biologists want from modellers, and modellers from biologists". Some of the mutual needs recognized were:

- Field observations need to be carried out on time and space scales that match processes,
- Time series must be of sufficient duration to capture eutrophication effects, which develop over the long-term,
- Modellers and biologists must consider the indirect impacts of nutrient supply rates and levels on phytoplankton behaviour, and not only direct effects,
- Bacteria, other heterotrophs and macroalgae should not be ignored, since they compete with phytoplankton for nutrients,
- Nutrient thresholds may occur, at which there may be increased potential for significant "bioshifts" in phytoplankton and/or higher trophic level responses. To guide modellers and managers, these thresholds and a "trophic index" or "saprobic system" which classifies habitat nutrient and trophodynamic status need to be established,
- Ecophysiological data on key species are needed, and ecophysiological groupings of phytoplankton at some level intermediate between their species and functional group affiliation would be helpful,
- While there may be increased risk of harmful algal bloom events with eutrophication, there are many instances in which this is not a factor. There should not be *a priori* anticipation that eutrophication will lead to harmful blooms, which are highly unpredictable, in their occurrence and bloom species,
- In modelling eutrophication effects, trophic transfer must be considered. Models need to incorporate food web - grazer interactions, and these trophic compartments monitored in the time series data being collected, particularly where management of nutrient supply and its effects are objectives,
- Follow up monitoring is required at sites where management of nutrient supply and its effects are objectives, particularly where the eutrophication process may have been reversed, and where there is need to establish whether the induced changes have long-term persistence.

Workshop participants, aware of the various definitions currently in vogue, did not seek to define eutrophication, and resisted temptations either to endorse (or reject) existing definitions, or to elaborate a consensus definition in replacement. All agreed that eutrophication is not a "state", stationary, or fixed condition, but a process in which there is a continuum of change and modified response. In this process, the natural habitat and its communities will degrade progressively and increasingly, unless the nutrient supply is diminished. The direction and velocity of this change will vary with the level and rate of nutrient supply, with the biotic responses further influenced by habitat conditions. The extent to which the process is reversible and the kinetics of nutrient induced change are obscure, however.

The Plenary discussion focused on the failure of the various definitions of eutrophication and their varying criteria to be generally applicable. Examples were presented to show that the application of existing eutrophication criteria could incorrectly designate a habitat as being eutrophicated, or would incorrectly explain observed phytoplankton behaviour as a response to eutrophication. These sobering insights contributed to the decision of Workshop participants to sidestep efforts at defining eutrophication. This decision was influenced by the fact that certain definitions have acquired quasi-legal status in serving as criteria that regulatory agencies are applying in seeking compliance with mandated reductions in nutrient loading (see Stephen Malcolm: Abstracts (Appendix 3)). Workshop participants agreed that there is need to reconcile existing definitions of eutrophication with scientific findings, such as reported at the Workshop, and that more workable definitions will evolve as the knowledge base increases. Just as the plenary discussions established that increased collaboration between biologists and modellers was needed, a similar need for collaboration between managers, regulatory agencies and "hard" scientists to develop such workable definitions of eutrophication was recognized.

6 PUBLICATION OF WORKSHOP PROCEEDINGS

Workshop participants not only presented and discussed their results enthusiastically, they were nearly unanimous in their desire to have the Workshop presentations published in the open, peer-reviewed literature. Dr Ing. Katja Philippart announced that the Journal of Sea Research, for which she is an Editor, would be willing to make a Special Issue, under Guest Editors, available for publication of the papers. Her offer was accepted and a formal request has been submitted to her for further review. Drs. Peter Bot, Paul Harrison, David Mills, and Ted Smayda have agreed to serve as Guest Editors, with Peter Bot serving as Chief Guest Editor. Specific instructions to authors and guidelines for preparation and submission of the manuscripts will be posted on the Workshop Website (Appendix 1), with manuscripts to be submitted by 1 October 2002.

An objective of the Plenary Session was to seek plenary consensus of Workshop participants with regard to the current status of, and types of investigative studies needed to quantify eutrophication impacts on phytoplankton dynamics. And, if achieved and deemed worthy of open dissemination, to summarize in a brief report, under the joint authorship of Workshop participants, the major Plenary Session conclusions and recommendations, and to submit it to Marine Pollution Bulletin or Ambio, for their consideration. The material presented in Section 5 of the Report would serve as the basis of this product. This option is now being explored among the Workshop conveners and participants. A currently prevailing view is that publication of the plenary consensus would reach a wider audience and be of interest to scientists, regulatory agencies and others in need of expert opinion without the underlying scientific detail. The latter would be made available in the publication of the Workshop proceedings in the Journal of Sea Research Special Issue being planned.

7 SUMMATION

In summary, the motivation behind the ICES WGPE recommendation to convene the Workshop (WKNUPE) was realized. Having the benefit of the quality presentations, insights and discussion of the invited participants, all having "hands on" research or practical experience relevant to the Workshop, WGPE members are better prepared to deal with related ToRs in the future. WGPE can also contribute to the needed refinement of a workable definition of eutrophication in joint effort with other ICES Working Groups and regulatory agencies, if called upon. The conveners have received many favourable comments on the Workshop presentations and the scientific exchanges that occurred, including comments that the Workshop served also as a tutorial for many attendees, and helped to build needed interdisciplinary bridges. A Plenary Session recommendation was that ICES should encourage Working Groups to convene similar Workshops having cross-disciplinary themes, and to which non-affiliated scientists are also invited. The increasing need to quantify the complex interactions driving marine ecosystems and their trophodynamics transcend science. This quantification is required for regulated harvesting of the sea, for managerial purposes, and accommodating other societal dependencies on the marine habitat. Working Groups could better respond to such social issues, which are often embedded within their ToRs, if they have had the benefit of interactive exchanges with other Working Groups in Workshops convened to deal with dedicated themes of mutual interest, but which require interdisciplinary effort. This insight, too, is a contribution from the multidisciplinary Workshop of scientists that WGPE convened to tutor in, synthesize and debate the influence of nutrient enrichment of coastal water ecosystems and altered phytoplankton behaviour.

APPENDIX 1: WEBSITE FOR ICES WORKSHOP ON CONTRASTING APPROACHES TO UNDERSTANDING EUTROPHICATION EFFECTS ON PHYTOPLANKTON

EutWork

A workshop on:

Contrasting Approaches to Understanding Eutrophication Effects on Phytoplankton

11–13th March 2002

http://www.cefas.co.uk/eutwork/default.htm

Overview	Guide to Speakers	Accommodation
Travel Details	Workshop facilities	Useful Links

Co-sponsors:

- National Institute for Coastal and Marine Management (RIKZ), The Hague, The Netherlands
- CEFAS, Lowestoft Laboratory, Lowestoft, UK
- ICES Working Group on Phytoplankton Ecology (WGPE)

In Association with:

The University of Rhode Island
and
SMHI, Sweden

To be held at:

RIKZ
Kortenaerkade 1
PO Box 20907
2500 EX Den Haag
The Netherlands

For information on travel and accommodation contact:

- Peter Bot (p.v.m.bot@rikz.rws.minvenw.nl)
  Kortenaerkade 1
  PO Box 20907,
  2500 EX Den Haag,
  The Netherlands
  Tel +31 70 3114 220

For general information on the workshop proceedings contact:

- Lars Edler (lars.edler@smhi.se)
  SMHI
  Ocean Laboratory
  Doktorsgata 9D
  262 52 Angelholm
  Sweden
  Tel +46 431 80854

or any of the organisers;

- Ted Smayda (tsmayda@gso.uri.edu)
  Graduate School Oceanography
  University of Rhode Island
  Kingston, RI 02881
  USA
  Tel +401 874 6171

- Dave Mills (d.k.mills@cefas.co.uk)
  CEFAS
  Lowestoft Laboratory
  Lowestoft, Suffolk NR33 0HT
  UK

Contrasting approaches to understanding eutrophication effects on phytoplankton

- **Co-chairmen: Peter Bot, David Mills, Lars Edler, Ted Smayda**

The ICES Working Group on Phytoplankton Ecology (WGPE) at its annual meeting, held in March 2001 in Bergen, Norway, recommended to ICES that a workshop be convened to consider the impacts of nutrient enrichment of coastal waters and inland seas on phytoplankton behaviour and accompanying trophic responses. The approaches taken to evaluate the effects of eutrophication on phytoplankton dynamics traditionally focus on biomass (usually chlorophyll) and primary production to the neglect of species succession and bloom responses, energy flow and food (prey) quality. The ICES WGPE identified this neglected aspect of nutrient loading effects on phytoplankton community behaviour, i.e., the organismal approach, as a topic of major relevance to the unresolved debate over the impacts of coastal eutrophication on phytoplankton processes.

ICES recently approved the convening of this Workshop, to be held on 11–13 March 2002, in The Hague, The Netherlands. The primary Workshop aim will be to evaluate the mass balance vs. organismic responses to quantify phytoplankton responses to coastal nutrient enrichment. In this evaluation, observational and experimental studies, both field and laboratory, are of interest, including regional ecology, population dynamics, cellular nutrient physiology and modelling. The Workshop objectives are to:

- identify the range of responses of phytoplankton communities to nutrient enrichment,
- evaluate the relative importance of cellular, population and community level responses to nutrient inputs,
- improve predictions of phytoplankton responses to nutrient inputs.

Plenary consensus of Workshop participants will be sought with regard to the current status of, and types of investigative studies needed to quantify eutrophication impacts on phytoplankton dynamics. The consensus arrived at will be formalized in a manuscript co-authored by Workshop participants for publication in Ambio, Marine Pollution Bulletin, or other journal. It will also be forwarded to ICES for its use. We are also exploring publication of the Workshop presentations in a peer-reviewed journal. Following the Workshop, the ICES Working Group on Phytoplankton Ecology will have its annual meeting on 14–16 March also in The Hague, The Netherlands. Workshop participants are welcome to join the meeting as observers.

Guide to speakers:

Time allocation

Please note your time allocation in the programme. We would like to allow ample time for discussion and would ask all speakers with a 30-minute or ample time for discussion and would ask all speakers with a 30-minute or longer slot to aim for allowing 10 minutes for discussion

Titles and Abstracts

This is a gentle reminder to all who have yet to send their final titles and abstracts. Please copy all abstracts to Dave Mills so that they can be included on the web site.

For those yet to submit, could you adhere to the following simple format?

Title in bold capitals with Time Roman font size 12 followed by author, address (including e-mail), with separate lines for each part, and abstract text all in Times Roman font size 10. See the abstracts already submitted for examples.

To see copies of the submitted abstracts go to the programme and follow the links under the paper titles.

Accommodation

Participants will be accommodated in the Park Hotel, Den Haag, unless you are otherwise informed.

Travel Details

Map showing how to reach RIKZ (PDF 306KB)

Workshop facilities

Talks will be given in the Lecture Theatre on the first floor of the RIKZ building (room 105). Audio Visual facilities include an overhead projector, a 35mm slide projector and a PowerPoint projector for Windows based presentation. It would be most convenient if speakers wishing to make PowerPoint presentations could put their presentation on to a CDROM.

Additional facilities will be available in room 102 near to the lecture hall for workshop participants.

Eating and drinking

Lunches will be provided free of charge at the RIKZ canteen which is close to the lecture room. An allowance will be paid to cover the cost of evening meals apart from Tuesday.

Workshop Dinner

On Tuesday evening a workshop dinner will be held at 19:45 hours at the SURAKARTA (Indonesian) restaurant. Please confirm your attendance by that day with Peter Bot.

Useful Links:
Netherlands train information
Den Haag tourist information

http://www.cefas.co.uk/eutwork/default.htm

APPENDIX 2: WORKSHOP PROGRAMME ON CONTRASTING APPROACHES TO UNDERSTANDING EUTROPHICATION EFFECTS ON PHYTOPLANKTON

Programme

CONTRASTING APPROACHES TO UNDERSTANDING EUTROPHICATION EFFECTS ON PHYTOPLANKTON

Sunday, 10 March 2002

Informal gathering on Sunday evening: Park Hotel Lounge, The Haag

Monday, 11 March 2002

No.	Start	Finish	Minutes	Activity
	08.30	09.25	55	Registration
	09.25	09.40	15	Welcome and Introduction **Ted Smayda**
1)	09.40	10.20	40	**Keynote:** Nutrient Limitation and Phytoplankton Growth: A Historical Perspective **Eystein Paasche**
2)	10.20	10.50	30	Society Needs to Manage Marine Eutrophication **Stephen Malcolm**
	10.50	11.15	**25**	**COFFEE**
			Session Chair: David Mills, CASE HISTORIES	
3)	11.15	12.05	50	**Keynote:** Eutrophication and Harmful Algal Blooms in the Seto Inland Sea **Ichiro Imai**
4)	12.05	12.35	30	Observations of Coastal Eutrophication and the Succession of Hab Species in Korean Waters Over Three Decades **Hak-Gyoon Kim**
5)	12.35	13.05	30	The Most Limiting Nutrient (Phosphorus) and Eutrophication in the Pearl River Estuarine Coastal Waters **Kedong Yin**
	13.05	14.05	**60**	**LUNCH**
6)	14.05	14.35	30	A plume river across the southern North Sea **Martien Baars**

7)	14.35	15.05	30	On The Role of Nutrients on Phytoplankton Blooms In The Skagerrak **Einar Dahl**
8)	15.05	15.35	30	Measurements of Primary Production in Kattegat and in Adjacent Waters of The Baltic Entrance Region: A Brief Historical Review **Lars Rydberg**
	15.35	16.00	**25**	**COFFEE**
9)	16.00	16.30	30	The Baltic Eutrophication Case History **Ragnar Elmgren**
10)	16.30	17.00	30	The Irish Sea: Nutrient Status and Phytoplankton **Richard Gowen**
11)	17.00	17.30	30	Long Term Nutrient Trends and Phytoplankton Response in Delaware Estuary, USA **Jonathan Sharp**
12)	17.30	18.00	30	Mucilage Formation in the Northern Adriatic Sea **Ulrich Horstmann**

Tuesday, 12 March 2002

Session Chair: David Mills, CASE HISTORIES (continued)

13)	08.30	09.00	30	Phytoplankton blooms in the Western part of the Black Sea in the 1990s **Violeta Velikova**
14)	09.00	09.30	30	Phytoplankton Gradients from Inshore to Offshore Waters of the Aegean Sea **Lydia Ignatiades**
15)	09.30	10.00	30	Consequences of Anthropogenic Eutrophication in the Kastela Bay (Adriatic Sea) **Ivona Marasovic**
	10.00	10.25	**25**	**COFFEE**

Session Chair: Lars Edler, DRIVING FORCES

16)	10.25	10.55	30	Coupling Between Climate Variability and Coastal Marine Eutrophication: Historical Evidence and Future Outlook **Dubravko Justíc**
17)	10.55	11.25	30	Freshwater Inputs **Tim Jickels**
18)	11.25	11.55	30	Variations in Nutrient Ratios and Aquatic Food Webs **Gene Turner**
19)	11.55	12.25	30	New Approaches to Detection and Assessment of Eutrophication **David Mills**

	12.45	13.45	**60**	**LUNCH**

Session Chair: Lars Edler, PHYSIOLOGY and NUTRIENTS

20)	13.25	14.15	50	**Keynote:** Screening Biogeochemical, and Ecological, Models of Enriched Marine Coastal Ecosystems **Paul Tett**
21)	14.15	14.45	30	Effects of Nutrient Emissions and Their Reduction on Phytoplankton in a Baltic Bay, Himmerfjärden, a 25-Year Study **Ragnar Elmgren and Ulf Larsson**
22)	14.45	15.15	30	Is phytoplankton a useful indicator for Wadden Sea eutrophication? **Justus van Beusekom**
	15.15	15.40	**25**	**COFFEE**
23)	15.40	16.10	30	Limits on The Predictability of Phytoplankton Competition **Jef Huisman**
24)	16.10	16.40	30	Silica Availability, Phytoplankton Species Composition, and Eutrophication **Quay Dortch**
25)	16.40	17.10	30	Nutrients and Dinoflagellate Life Cycles **Yasuwo Fukuyo**
26)	17.10	17.40	30	The Effects of Reduced Nutrient Loadings in Dutch Coastal Waters **Theo Prins**

WORKSHOP DINNER AT 19:45

Wednesday, 13 March 2002

Session Chair: Lydia Ignatiades, MASS BALANCE AND MODELLING**

27)	08.30	09.20	50	**Keynote:** Eutrophication and Altered Phytoplankton Behaviour: Biomass Versus Species-Based Approaches **Ted Smayda**
28)	09.20	09.50	30	Three Dimension (3D) Ecological Modelling of the “Baie de Seine” (English Channel, France) **Philippe Cugier**
29)	09.50	10.20	30	Modelling Phaeocystis Blooms in the Southern Bight of the North Sea in Response to Short-term Climate and Anthropogenic Changes **Christianne Lancelot**
	10.20	10.45	**25**	**COFFEE**
30)	10.45	11.15	30	Modelling (Nuisance) Algal Physiology **Kevin Flynn**

31)	11.15	11.45	30	Nutrient Budgets for the Western Wadden Sea **Katja Philippart**
32)	11.45	12.15	30	Estimating Regional and Cross-Boarder Eutrophication Problems, and The Potential Effects of Management Actions **Einar Svendsen**
33)	12.15	12.45	30	ERSEM Approach to modelling Eutrophication Effects **Job Baretta**

(** A Presentation on Modelling the Baltic Sea to have been presented by Dr Fredrick Wulff was cancelled because of illness)

	12.45	13.45	**60**	**LUNCH**

PLENARY SESSION, Session Chair: Franciscus Colijn

34)	13.45	14.30	45	Workshop Synthesis **Paul Harrison**
	14.30	15.00	**30**	**COFFEE**
	15.00	16.30	90	Plenary Session Discussion
	16.30	16.45	15	Closing Remarks **Ted Smayda**

APPENDIX 3: WORKSHOP ABSTRACTS

CONTRASTING APPROACHES TO UNDERSTANDING EUTROPHICATION EFFECTS ON PHYTOPLANKTON

11–13th March 2002

ABSTRACTS

A PLUME RIVER ACROSS THE SOUTHERN NORTH SEA

Martien A. Baars
Dept. Biological Oceanography, NIOZ,
Texel,
The Netherlands
E-mail: baars@nioz.nl

Satellite images show a marked plume of suspended matter from Norfolk stretched north-eastwards in the direction of the residual currents into the open Southern Bight. This East Anglian Silt Plume temporarily sediments at the transition on the Dutch Continental Shelf between the shallow (25 m) Texel and Vlieland Grounds and the deeper (50 m) Oyster Ground: the Frisian Front. The new programme 'Plume & Bloom' studies the hydrography and plankton dynamics over this whole central area of the Southern Bight in order to test the hypothesis that English Coastal Water could be a nutrient source at the Frisian Front late in the productive season. Results of a series of cruises during July-December 2000, showed a robust hydrographic structure. In between the Central North Sea Water in the north and the tongue of Channel Water in the south, there was a marked 'river' of English Coastal Water. The 'river' was largely situated within the East Anglian Silt Plume. Turbidity in the Plume during summer was relatively low, and underwater light conditions were good enough for phytoplankton production. During moderate wind, diatoms grown in the English coastal waters became mineralised in the Silt Plume, as ammonia and silicate concentrations increased from west to east. In addition, periods with strong western winds, and consequently fast residual currents, seemed to generate pulses of UK river nutrients into the Silt Plume. The visual effect of this load of regenerated and/or new nutrients seem to depend on the wind regime. With strong SW winds, the 'river' ended well north in the Oyster Ground, where water column depth was too large to give dense blooms. With strong NW winds, the 'river' was pushed on the upper slope and the shallow sands south of the Frisian Front, and blooms developed there. Not at the Frisian Front proper, since turbidity there was generally too high, due to the tidal resuspension of the mud-rich slope zone.

ERSEM APPROACH TO MODELLING EUTROPHICATION EFFECTS

Job Baretta
National Institute for Coastal and Marine Management/RIKZ
PO Box 20907
2500 EX Den Haag
The Netherlands
E-mail: j.w.baretta@rikz.rws.minvenw.nl

The European Regional Seas Ecosystem Model (ERSEM) is a set of biogeochemical modules describing the cycling of carbon, the macro-nutrients N, P and Si and oxygen (O) through the lower trophic levels in temperate shelf seas. It has been developed, refined and applied in Marine Science and Technology (MAST) projects by shifting consortia of leading marine science institutes in Europe. The biological resolution of the model is high, much too high in the eyes of many non-biologists, much too low in the eyes of many biologists. The model has been applied to aquatic systems ranging from mesocosms in Danish waters and Norwegian fjords, via 1DV representations of Baltic sub basins (Bornholm, Gotland) and the Northern Adriatic to pseudo- or full 3D setups of the North Sea and the Adriatic. The biology in all these setups is exactly the same, with the physical model (usually a hydrodynamical model) providing the spatially and temporally different abiotic information (transport/mixing) to the biology and the biology modifying the abiotic environment (production/consumption). The biology being formulated identically everywhere, but expressing itself widely differently in the different systems it has been applied to, implies that ERSEM is well on its way to meeting its prime objective of being a generic formulation of marine ecosystem function. It has the capability of addressing (and maybe even laying to rest) some of the apparent paradoxes in marine ecology such as bottom-up vs. top-down control, bacterioplankton being a sink or a link to higher trophic levels, the consequences of nutrification at a system level etc. The major problem with ERSEM is the coupling of the biological model to different 3D hydrodynamical models to be used. This coupling preferably is bi-directional, in order to allow the expression of the

biology modifying the physical state of the system (e.g., modification of the heatflux into the watercolumn, modifying vertical mixing rates).

THREE DIMENSIONAL (3D) ECOLOGICAL MODELLING OF THE "BAIE DE SEINE" (ENGLISH CHANNEL, FRANCE)

Philippe Cugier
IFREMER/Centre de Brest
DEL-EC-BB
B.P. 70
29280 Plouzané
France
E-mail: pcugier@ifremer.fr

The Bay of Seine receives the Seine River, which exhibits very high nutrient concentrations, and this coastal zone constitutes a typical case of eutrophication in a river plume area with chlorophyll a concentration reaching regularly 40 µg/l. A three dimensional (3D) ecological model is developed and applied to the Bay of Seine area. It consists of a 3D model for hydrodynamics and sediment transport (SiAM3D) coupled to an ecological model simulating nutrient cycles (nitrogen, phosphorus, silicon) and two phytoplanktonic classes (diatoms and flagellates). The model is validated by confronting simulations with nine yearlong series of measurements and then used to better understand the ecosystem functioning. It quantified the limitation of each of the three nutrients. In spite of nitrogen loading increase from the last twenty years, no phytoplanktonic stock increase has been observed. This may be explained by the phosphorus loading reduction during the same period and the model shows the reversing influence of nitrogen and phosphorus limitation. The model also allows showing the role of the proportion of silicon with regard to nitrogen and phosphorus in the summer loadings of the Seine River on the more or less strong presence of flagellates in the plume. Finally, the model was used to test various hypotheses of reduction of nitrogen and phosphorus loading of the Seine river and their consequences on the phytoplanktonic production in the plume.

ON THE ROLE OF NUTRIENTS ON PHYTOPLANKTON BLOOMS IN THE SKAGERRAK

Einar Dahl
Institute of Marine Research
N-4817 His
Norway
E-mail: einar.dahl@imr.no

Skagerrak is a transition area between the Kattegat/Baltic and the North Sea. It is essentially flushed through by brackish water from the Baltic via Kattegat, "polluted" water from the German Bight via the Jutland current and "pristine" Atlantic water via the northern North Sea. The overall annual current pattern is an anti-clockwise circulation with inflow in the south of Skagerrak and outflow in the north, in westward direction along the southern coast of Norway. The speeds and directions of the surface currents can, however, change a lot and rapidly, mainly due to shifts in the weather, i.e., wind and pressure. Accordingly environmental parameters such as temperature, salinity and nutrients also may change rapidly and over a wide range. This highly dynamic environment of the upper layers of the Skagerrak is reflected by a productive and diverse phytoplankton society in the area. When the phytoplankton society from nature is rich and frequently changing, it is difficult to detect possible trends, and any changes, for instance due to effects of nutrients, can be masked or mistaken by effects of climate (temperature). For about two decades, most regularly since 1989, a monitoring of chlorophyll a and selected harmful phytoplankton species has been performed in the Skagerrak with two main objectives; 1) early warning of potential harmful bloom and 2) accumulation of reliable data for scientific purposes, as trends analyses and studies of relations between occurrences of phytoplankton and environmental factors. Intensified field studies, to learn from nature, have been organized when harmful blooms, such as *Karenia mikimotoi, Chrysochromulina polylepis, Chattonella* spp, and *Dinophysis* spp., have afflicted the Skagerrak. The existing long-term data of oxygen in the depth of the central Skagerrak and in the depth of basins along the Norwegian coast are considered of relevance in understanding possible shifts in phytoplankton amounts and composition over time. Our long-term oxygen data reveal increased consumption in basins along the coast, leading to lower levels than before. This is due to increased sedimentation of organic material, and may reflect increased new production of phytoplankton along the coast, possibly combined with a shift in species composition and less grazing. Our time series on harmful species are too short to reveal any obvious trends, but analyses of occurrence of selected species in relation to the nutrient conditions suggest some interesting connections. Blooms of *Chrysochromulina* spp. and *Chattonella* spp. seems more directly dependent on the nutrient conditions than blooms of *Karenia mikimotoi and Dinophysis* spp.

SI AVAILABILITY, PHYTOPLANKTON SPECIES COMPOSITION, AND EUTROPHICATION

Quay Dortch[1] and Nancy N. Rabalais[1] and R.E. Turner[2]

[1]Louisiana Universities Marine Consortium, 8124 Highway 56, Chauvin, Louisiana 70344, USA; [2]Coastal Ecology Institute and Dept of Oceanography and Coastal Science, Louisiana State University, Baton Rouge, LA 70803, USA,

E-mail: qdortch@lumcon.edu; nrabalais@lumcon.edu; euturne@lsu.edu

Most studies of eutrophication focus on the consequences of increasing inputs of N and P in coastal waters but ignore decreasing or stable Si inputs. While increasing N and P are the cause of many of the harmful effects associated with increasing eutrophication, the changes in Si relative to N and P availability may have a profound effect on the impacts of eutrophication. The most obvious is the switch from diatoms to non-diatoms (see Turner *et al.*). Diatoms are usually associated with greater vertical carbon flux, either directly due to sinking cells or indirectly due to enhanced zooplankton grazing and production of sinking fecal pellets, both of which contribute to the formation of hypoxic bottom water. Non-diatoms may not contribute as much to vertical carbon flux as diatoms. In addition since most Harmful Algal Bloom species are non-diatoms, HABs have been hypothesized to increase when Si is limiting. In reality the situation is much more complex because the response is often dependent on the individual species that dominate. Some ecosystems are either intermittently or borderline Si limited which allows diatoms with low Si requirements to dominant, rather than resulting in a shift to non-diatoms. Not all diatoms contribute equally to carbon flux and this may be determined in part by Si availability. Further, diatoms can be toxic or harmful, for example, some *Pseudo-nitzschia* spp. or *Chaetoceros* spp., and the dominance of some non-diatom HABs, such as colonial cyanobacteria, appear often to be independent of Si availability. Finally, for both diatoms and non-diatoms, other environmental factors may interact with silicate availability to determine which species predominate. In future research much greater emphasis needs to be placed on the role of individual species in determining the impacts of eutrophication and the role of Si availability should always be evaluated.

THE BALTIC EUTROPHICATION CASE HISTORY

Ragnar Elmgren
Department of Systems Ecology
Stockholm University
SE-10691 Stockholm,
Sweden
E-mail: ragnar_e@system.ecology.su.se

The Baltic is a large brackish sea, 4 x 10^5 km^2, extending from 54°N to ~66°N, with a fourfold larger drainage area (population 8 x 10^7). Surface salinity (2–8 psu) and, hence, biodiversity is low. Last century, annual N and P loads increased several-fold, to 10^6 metric ton N, and 5x10^4 tons P. Eutrophication symptoms are most clearly evident in the N-limited southern half, the Baltic proper, where Secchi depths have been halved, and oxygen-deficient bottom areas have spread, whereas the P-limited north still has low productivity. In the N-limited Baltic proper, summer blooms of cyanobacteria fix 200,000 to 400,000 tons N each year. In eutrophicated coastal areas, amenity value is reduced by phytoplankton blooms, which are sometimes toxic, and mass development of filamentous macroalgae. Baltic countries report some success in reducing loads of P, but little for N. Where substantial N-load reductions have been achieved locally, algal biomass has declined. Loads need to be reduced of both N, to reduce production, and P, to limit blooms of nitrogen-fixing cyanobacteria. If in the future, reduction is more effective for P than for N, an artificially P-limited Baltic proper may result, very different from its natural N-limited state. The political goal of halving anthropogenic N and P loads requires continued reduction of emissions to the sea, and will be helped by continued high takes by the fishery, which incidentally removes some circulating nutrients.

EFFECTS OF NUTRIENT EMISSIONS AND THEIR REDUCTION ON PHYTOPLANKTON IN A BALTIC BAY, HIMMERFJARDEN, A 25-YEAR STUDY

Ragnar Elmgren and Ulf Larsson
Department of Systems Ecology
Stockholm University
SE-10691 Stockholm,
Sweden
E-mail: ragnar_e@system.ecology.su.se

The ecological effects of the nutrient discharge of the Himmerfjärden STP (now serving 250 000 people) was followed in 1976–2000. Particular emphasis is given the introduction of 90% nitrogen from mid-1997, studied in the MISTRA research programme SUstainable COastal ZOne Management (SUCOZOMA). Pre-reduction measurements from 1977–1996 showed that the large nitrogen load generally made phytoplankton in inner Himmerfjärden Bay phosphorus-limited, except in late summer, when sediment release of phosphorus caused nitrogen limitation. Following N-reduction in the STP, nitrogen concentrations decreased markedly in the Bay, giving lower phytoplankton biomass (as chlorophyll a) both during the spring bloom and the summer, and as annual averages, but there were only a minor reduction in Secchi depth (primarily during spring). No clear effect on oxygen consumption in the deep water can yet be discerned. Phytoplankton limitation by N, or N and P co-limitation, has now become dominant in the bay, with increasing nitrogen limitation towards the open sea, which is N-limited, except during summer blooms of nitrogen-fixing cyanobacteria. As predicted, nitrogen-fixing cyanobacteria blooms appeared in the bay system after reduction of the N load. These blooms are probably phosphorus-limited, but other phytoplankton seem to be co-limited by N and P during the blooms. Their stoichiometry shows that filamentous nitrogen-fixing cyanobacteria are less severely phosphorus limited in Himmerfjärden Bay than in the open Baltic, and their stable nitrogen isotope ratios show that they are as dependent on fixed nitrogen in the Bay as in the open sea. Ongoing studies include experiments where more nitrogen is released for a period in late spring-early summer, to keep the availability of N and P balanced near the Redfield ratio of 16 (by atoms), and hence prevent or reduce the development of cyanobacterial blooms in the bay system.

Modelling (Nuisance) Algal Physiology

K.J. Flynn
Ecology Research Unit,
Wallace Building,
University of Wales
Swansea, SA2 8PP,
UK
E-mail: k.j.flynn@swansea.ac.uk

A comparative overview will be given of the range of models available for simulating the growth of microalgae, balancing the needs for simplicity versus realism. With the appreciation of the true complexity of algal ecophysiology, multi-nutrient models are required. However, simple models for the description of multi-nutrient interactions may contain constructional errors that invalidate their output. If the construction is inadequate, although growth may be correctly simulated, the removal of lesser-limiting nutrients (the availability of which affects subsequent generations) is prone to serious errors. A simplified model for ammonium-nitrate-P-Si-Fe-light interactions has been developed that offers a suitable compromise for placement in ecosystem simulators. As an example of the utility of multi-nutrient algal models, the results of simulations in which a detailed model of N-P interactions in PSP producing *Alexandrium* is run within a vertical water structure (allowing DVM) will be shown. This predicts that highly toxic cells may grow at even moderately elevated N:P.

NUTRIENTS AND DINOFLAGELLATE LIFE CYCLES

Yasuwo Fukuyo
Asian Natural Environmental Science Center,
University of Tokyo
Yayoi, Bunkyo-ku, Tokyo 113–8657,
Japan
E-mail: ufukuyo@mail.ecc.ut-tokyo.ac.jp
fukuyo2002@yahoo.com

Among 2000 modern dinoflagellates, only 1/20 of the species have been reported to produce resting cysts. The sexual reproduction process, in which cyst stage is included, has been clarified for only very few species such as *Alexandrium* *tamarense, A. catenella, Scrippsiella trochoidea, Pyrophacus steinii*, and *Gymnodinium instriatum*. Only fragmental data from field observation and laboratory experiments are available to analyse factors controlling the process. But some observation indicates N and P nutrient levels have implication to the process, especially gamete formation and transformation from planozygotes into hypnozygotes (resting cysts). Gamete formation and their fusion, i.e., planozygote formation, are observed during the active growing period of blooms. Frequent binary fission of vegetative cells induces cell size smaller, and the small size cells produced show behaviour of gametes (dancing, paring and fusing). Enforced separation of gametes followed by an inoculation into nutrient rich medium makes the gametes onset of asexual fission. The success rate of hypnozygote formation from planozygotes is also high during the logarithmic growth period of blooms in cases of *A. tamarense* and *A. catenella* in the field. But the inoculation of the planozygotes into new nutrient rich medium in laboratory using field specimen does not lead to change into hypnozygotes, but to start asexual fission. Usually in the field, the active asexual growth is supported by high concentration of N and P. Therefore high nutrient concentration looks like supporting sexual process also. But completion of sexual process looks need low nutrient condition. Quite low concentration of P used for induction of sexual process in laboratory experiments may have implication to the hypothesis.

THE IRISH SEA: NUTRIENT STATUS AND PHYTOPLANKTON

Richard Gowen
Department of Agriculture and Rural Development for Northern Ireland
Agriculture and Environmental Science Division
Newforge Lane
Belfast BT9 5PX,
UK
E-mail: richard.gowen@dardni.gov.uk

The Irish Sea is a semi-enclosed coastal sea. Exchange with open shelf waters is restricted by narrow channels to the north and south and the residence time of water within the sea is (one year. There is considerable potential for nutrient recycling within the Irish Sea although the autumn /winter build up of dissolved inorganic nitrogen is due in part to the introduction of new nitrogen. The main external sources of nitrogen for the Irish Sea are marine (the Atlantic) and anthropogenic (land-runoff and atmospheric). Understanding of exchange processes across the shelf is limited and constrain attempts to quantify the Atlantic source term. The Celtic and Irish seas currently receive 130,000 t N, 6,000 t P and 34,000 t of Si and the Irish Sea is undoubtedly enriched with nitrogen, phosphate and silicate. Denitrification may limit the extent of nitrogen enrichment. Time-series observations of phytoplankton community structure are lacking for the Irish Sea making it difficult to evaluate the effects of enrichment. A recent study of Liverpool Bay and Irish coastal waters documented elevated spring production and biomass in the Bay but only small differences in species composition were apparent between the two sites. In offshore western Irish Sea waters, diatom and flagellate dominance of the spring bloom switches from year to year and may indicate that the western Irish Sea is undergoing a transition.

MUCILAGE FORMATION IN THE NORTHERN ADRIATIC SEA

Ulrich Horstmann
Institut für Meereskunde an der Universität Kiel
Düsternbrooker Weg 20
24105 Kiel,
Germany
E-mail: uhorstmann@ifm.uni-kiel.de

In the frame of an EU - context project investigations on the formation of mucilage in the northern Adriatic Sea were undertaken from 1993 to 1998. *In situ* measurements during transects across the northern Adriatic Sea, including underwater video observations and mucus sampling by divers, as well as laboratory experiments, lead to the following conclusion on mucus formation.

River water induced eutrophication causes phytoplankton blooms in the north-western part of the Adriatic Sea. Rapid and complete phosphorus uptake and sedimentation of the major part of phytoplankton biomass in summer depletes phosphate from the euphotic zone with a consequent strong excretion of dissolved and particulate organic carbon via phosphorus-limited phytoplankton metabolism. Colloids and fibrils of phytoplankton-excreted carbohydrates, when maintained for a longer period in the water column, aggregate especially during quiet weather conditions when density discontinuities occur. Colloids form large macroflocks and mucoid stringers. As aggregates are maintained in the water column for weeks, further aggregation and formation of mucoid clouds and carpets at the pycnocline takes place. This material can sink to the sea bottom where it is frequently observed by fishermen, also in years when no mucilagine appears at the sea surface. During summers when the cyclonic northern Adriatic gyre develops the mucoid material is advected to the northeastern, northern and finally northwestern parts of the Adriatic Sea, where increased concentrations of new and regenerated phosphorus have been measured. Increased nutrient levels, however, promote epi- and endomucoid growth of benthic diatoms and other microalgae. Photosynthesis-induced oxygen bubbles, which stick to - and are enclosed in - the mucoid material cause upwelling to the water surface. Wind-driven transport forces the mucilage to accumulate, leading to the mucilagine phenomenon along the beaches. Satellite images of sea surface temperature and watercolour are capable to detect the occurrence of the northern Adriatic gyre and consequently may predict mucilagine events.

LIMITS ON THE PREDICTABILITY OF PHYTOPLANKTON COMPETITION

J. Huisman[1] and F.J. Weissing[2]

[1]IBED, Faculteit der Natuurwetenschappen, Wiskunde en Informatica, Nieuwe Achtergracht 127, 1018 WS Amsterdam, The Netherlands. [2]University of Groningen, The Netherlands

E-mail: jef.huisman@science.uva.nl

There are thousands of different phytoplankton species, slowly drifting in lakes and oceans. Some of these phytoplankton species are toxic, whereas others are relatively harmless. Some of these species are edible for zooplankton, whereas others are not eaten at all. Can we predict which of these species will become dominant? Here, we argue that there are limits on the predictability of phytoplankton competition. Competition for one or two resources in a constant environment is highly predictable. However, more intricate competitive interactions may exhibit chaotic dynamics. In particular, multispecies competition models can have several alternative outcomes of competition. We show that these alternative outcomes of competition can be intermingled in the form of a fractal structure. As a result of the fractal geometry, it is fundamentally impossible to predict the winners of multispecies competition far in advance. We therefore advocate a similar approach as in the weather forecast. Short-term predictions of changes in species composition are feasible, but long-term predictions are troublesome. Knowledge of the time scales of plankton processes may indicate proper time horizons for the predictability of phytoplankton species composition.

Reference:

Huisman, and Weissing. 2001. Fundamental unpredictability in multispecies competition. American Naturalist 157: 488–494.

Phytoplankton Gradients from Inshore to Offshore Waters of the Aegean Sea

Lydia Ignatiades
Institute of Biology, National Centre for Scientific Research "Demokritos"
P.O. Box 60228
Aghia Paraskevi
Athens 15310,
Greece
E-mail: igna@mail.demokritos.gr

Inshore-offshore and north-south gradients of physical (temperature, salinity, underwater light penetration), chemical (nutrients) and biological (chlorophyll, primary production) parameters have been investigated in he Aegean Sea, Eastern Mediterranean. Data (annual means) collected from the inshore-offshore waters of Saronicos Gulf showed well defined gradients of nutrients (P-PO_4: 0.68–0.14μM; N-NO_3 + NO_2: 1.51–0.85 μM; N-NH_3: 2.20–1.05 μM; Si-SiO_2: 4.91–3.94 μM), chlorophyll (1.06–0.49 mg m^{-3}), primary production (2.54–1.46 mgC.m^{-3}.h^{-1}), and the depth of the euphotic zone (25–55 m). Data (seasonal means) collected from the north-south pelagic area of the Aegean Sea showed that both regions were oligotrophic, having very low levels of nutrients (P-PO4: 0.03–0.03μM; N-NO_3 + NO_2: 0.62–0.45 μM; N-NH_3: 0.31–0.12 μM; Si-SiO_2: 1.41–1.67 μM). However, well defined spatial north-south gradients of chlorophyll (0.33–0.23 mg m^{-3}), primary production (0.86–0.37 mgC.m^{-3}.h^{-1}), and the depth of the euphotic zone (90–120 m) were recorded. The picoplankton predominated and accounted for 56% to 49% of total chlorophyll, and 51% to 21% of total primary production in the North and South Aegean Sea, respectively.

EXPERIENCE OF EUTROPHICATION AND HARMFUL ALGAL BLOOMS IN THE SETO INLAND SEA, JAPAN

Imai I[1], Yamaguchi, M.[2], Hori T.[3]

[1]Laboratory of Marine Environmental Microbiology, Division of Applied Biosciences, Graduate School of Agriculture, Kyoto University, Kyoto 606–8502, Japan. [2]Red Tide Research Division, National Research Institute of Fisheries and Environments of the Seto Inland Sea, Ohno-cho, Saeki-gun, Hiroshima 739–0452, Japan. [3]Hyogo Prefectural Fisheries Experimental Station, Futami, Akashi, Hyogo 674–0093, Japan.

E-mail: imai1ro@kais.kyoto-u.ac.jp

The incidents of noxious red tides had dramatically increased in frequency and scale in Japanese coastal waters, especially in the Seto Inland Sea, along with serious eutrophication in 1960s and 1970s. The maximum incident 299/yr was recorded in 1976. The most important red tide organisms causing huge fishery damages by fish-kill were *Chattonella antiqua, C. marina* and *Heterosigma akashiwo* (Raphidophyceae), and *Gymnodinium (Karenia) mikimotoi* (Dinophyceae). The maximum fisheries damage (death of 14 million yellowtails) was 7.1 billion yen caused by *C. antiqua* in Harima-Nada in 1972, which is the world record. Average economic loss has been estimated to be about 1 billion yen per year thereafter in the Seto Inland Sea. "Law Concerning Special Measures for Conservation of the Environment of the Seto Inland Sea" was legislated in 1973 and industrial loading was decreased to half of the level of 1972. The level of nutrient salts had been lowered and red tide incidents had consequently decreased thereafter and reached about 100/yr in late 1980s, but this level of red tides has been kept so far with the level of nutrients supporting red tides. In 1990s, however, new red tide dinoflagellate species, *Heterocapsa circularisquama* appeared and has killed bivalves of both nature and culture recurrently. Moreover, the toxic dinoflagellate *Alexandrium tamarense* has become dominant in the Seto Inland Sea in spring season, and made cultured oyster toxic almost every year. More efforts are needed for understanding, forecasting, and preventing harmful algal blooms.

FRESHWATER INPUTS

Tim Jickells
Laboratory for Global Marine and Atmospheric Chemistry
University of East Anglia
Norwich NR4 7TJ
UK
E-mail: t.jickells@uea.ac.uk

I will briefly consider the nature of groundwater, atmospheric and riverine inputs to marine systems noting temporal and spatial variability in magnitude and nature. The talk will mainly focus on the role of nutrient inputs, but will also consider briefly other mechanisms by which freshwater inputs impact phytoplankton growth. The talk will attempt to address the question of whether inputs as measured at a monitoring site can be extrapolated to the key areas relevant to phytoplankton growth.

COUPLING BETWEEN CLIMATE VARIABILITY AND COASTAL MARINE EUTROPHICATION: HISTORICAL EVIDENCE AND FUTURE OUTLOOK

Dubravko Justic
Coastal Ecology Institute,
Department of Oceanography and Coastal Sciences,
Louisiana State University,
Baton Rouge, LA 70803,
USA
E-mail: djusti1@lsu.edu

The incidence and severity of eutrophication have increased during the last five decades in many estuarine and coastal areas, particularly those affected by riverine freshwater and nutrient inflows. This worldwide trend has been paralleled by an increase in the riverine concentrations of dissolved nitrogen and phosphorus, which has occurred as a result of fertilizer and detergent use in the watersheds. Temporal and spatial associations between the use of nutrients in the watersheds and outbreaks of eutrophication provide convincing arguments for the hypothesis that eutrophication is primarily driven by the by the increasing anthropogenic nutrient loads. At present, however, little is known about the linkages between climate variability, riverine nutrient fluxes, and coastal marine eutrophication. It was observed that short-term climate anomalies, such as droughts and floods, may substantially alter nutrient delivery to the coastal ocean, and influence surface net productivity, vertical flux of carbon, and oxygen depletion in bottom waters. The northern Gulf of Mexico, which is strongly affected by the Mississippi River, the sixth world largest river, provides ample opportunity to study such influences. Retrospective analyses have revealed pervasive control of variations in the Mississippi River freshwater and nutrient fluxes on oxygen and carbon cycling in the northern Gulf of Mexico. Model simulations for a 2xCO2 climate projected that a change in the global oxygen and carbon budgets would be of the same magnitude, or higher, than that resulting from five decades of anthropogenic eutrophication.

OBSERVATIONS OF COASTAL EUTROPHICATION AND THE SUCCESSION OF HAB SPECIES IN KOREAN WATERS OVER THREE DECADES

Kim, Hak-Gyoon, Sam-Geun Lee, Chang-Su Jeong
Marine Environment,
Oceanography and Harmful Algal Blooms Research Department,
National Fisheries Research and Development Institute
Busan, 619 - 900,
Republic of Korea
E-mail: hgkim@haema.nfrda.re.kr

The concentration of dissolved inorganic nitrogen and phosphate in Korean coastal waters has increased over the last three decades. The N/P ratio shows no significant inter-annual change with the exception of the abnormal surplus of nitrogen and phosphate in some waters. Until the 1970s, the outbreaks of harmful algal blooms (HABs) were rare and sporadic, but the frequency and persistence increased during the 1980s. During the last decade, HABs became widespread encompassing the whole coast and persisting more than one month. The gradual coastal eutrophication is consistent with widespread and persistent HABs. The prevailing species in HABs were diatoms until the 1970s, but the dinoflagellates have been responsible for most of the monospecific and persistent HABs since 1981. In the last decade, the dominant dinoflagellates were *Heterosigma akashiwo*, *Prorocentrum micans, Noctiluca scintillans,* and *Cochlodinium polykrikoides*. Among them, *C. polykrikoides* has made the most widespread and persistent blooms, extending along the whole southern and eastern coast of Korea. This high density of monospecific *Cochlodinium* blooms has caused consecutive fisheries damages since 1995. According to the coastal HABs monitoring, spring diatom blooms dominated by *Skeletonema costatum* are replaced by *Heterosigma akashiwo* and then *Prorocentrum* spp. Following these, *C. polykrikoides* is responsible for the summer harmful dinoflagellate bloom. *Skeletonema costatum* and *Thalassiosira* spp. gradually become predominant in fall, and transition into the winter community is completed. It is clarified that the development of coastal eutrophication leads to frequent, widespread and persistent dinoflagellate blooms, and causes species succession towards high growth and motile species.

MODELLING PHAEOCYSTIS BLOOMS IN THE SOUTHERN BIGHT OF THE NORTH SEA IN RESPONSE TO SHORT-TERM CLIMATE AND ANTHROPOGENIC CHANGES: RESULTS OF THE BELGIAN AMORE PROJECT (1997–2001)

Christiane Lancelot[1], Kevin Ruddick[2], Yvette Spitz[3], Elsa Breton[1], Véronique Rousseau[1]

[1]Ecologie des Systémes Aquatiques, Université Libre de Bruxelles; [2]Management Unit of North Sea Mathematical Models; [3]Oregon State University

E-mail: lancelot@ulb.ac.be

AMORE (Advanced Modelling and Research on Eutrophication) is a Belgian-funded interdisciplinary consortium composed of biologists and physical and ecological modellers focusing research activities on coastal eutrophication with special interest in harmful algal blooms. The long-term objective of AMORE is to develop an integrated environmental research methodology for managing water quality and resources of the nutrient-enriched *Phaeocystis*-dominated coastal North Sea ecosystem, focusing on the Belgian coastal zone (BCZ). Winter nutrient signature of BCZ shows indeed a NO_3 excess with respect to PO_4 and $Si(OH)_4$ which reflects the cumulative inputs of nutrients from atmospheric and direct sources, Scheldt, Ijzer and Rhine rivers, local benthic remineralization and the in-flowing Atlantic waters. The latter are themselves enriched by nutrient loads by the river Seine and Somme and direct coastal effluents. The questions addressed by AMORE are: (i) the natural capacity of coastal ecosystems to assimilate nutrients originating from land-based sources; (ii) the level of nutrient reduction required to protect living resources from the harmful effects of nutrient enrichment; (iii) the monitoring of positive/negative effects of current nutrient reduction programs. The chosen research methodology includes and combines observation, experimentation and numerical work as follows:

- High time-resolution monitoring of nutrients and algal blooms at station 330 of the Belgian monitoring network chosen as reference station since 1988 for its average properties with respect to Belgian coastal waters;
- Statistical analysis of the 10 year time series data set of nutrients and diatom-Phaeocystis successions at station 330 and relevant data on meteorological conditions and nutrient loads by the river Seine, Scheldt and Rhine;
- Process-level studies under field and laboratory-controlled conditions of key phyto- zoo- and bacterio-plankton communities;
- Implementation of the three-dimensional ecological model 3D-MIRO&CO based on the online coupling between the existing COHERENS 3D hydrodynamic model set up for the region between 51^{o}N and 52.5^{o}N using a horizontal grid of ~ 4.5km and an improved version of the MIRO ecological model. The latter was based on new knowledge gained from process studies and making use of new data assimilation techniques.

Main results obtained show that *Phaeocystis* colonies recurrently bloom after a modest early-spring diatom bloom limited by $Si(OH)_4$ and PO_4 availability. Success of *Phaeocystis* colonies rely on both its resistance to grazing by indigenous copepods and its ability to grow on excess NO_3 left over at diatom decline and regenerated PO_4. Statistical analysis of the 330 time-series revealed a complex interaction between the climate (NAO) and anthropogenic activities (land-based nutrients), which has a strong impact on the nutrient signature of the Belgian coastal waters. Shortly, years with positive NAO index were showing a higher influence of nutrient-enriched in-flowing Atlantic waters in the Belgian coastal zone and at station 330 in particular. Altogether it is suggested that between 1992 and 2000, the magnitude of *Phaeocystis* blooms at station 330 was controlled by P loads discharged by the River Seine.

Model runs with 3D MIRO&CO show reasonable agreement with current knowledge of *Phaeocystis* blooms magnitude and spreading in the Southern Bight of the North Sea. In particular the model reproduces quite well the short explosive single *Phaeocystis* bloom of late April-early May in the Belgian coastal waters as well as the multiple blooms observed in the Dutch area between April and September. Sensitivity tests with changing weather conditions (year with high vs low NAO) and nutrient inputs by in-flowing Atlantic waters and rivers indicate that future policies of nutrient reduction are expected to reduce the intensity of *Phaeocystis* blooms but the extent of this drop will be modulated by NAO change.

SOCIETY NEEDS TO MANAGE MARINE EUTROPHICATION

Stephen J Malcolm
CEFAS Lowestoft Laboratory
Pakefield Road
Lowestoft NR33 0HT
UK
E-mail: s.j.malcolm@cefas.co.uk

Marine eutrophication has been identified as an issue worth managing for several decades but the reasons why it should be managed has often been left to belief rather than a clear definition of the problem. Debate about a definition of the phenomenon has been fierce and has resulted, in Europe, in a workable definition that combines cause (nutrient enrichment) with a primary response (plant growth) that can lead, in the right (or wrong!) circumstances, to undesirable disturbance of the ecosystem or water quality. The clarity of the definition is often lost when scientists continue to equate eutrophication with either nutrient enrichment or enhanced growth on its own. Managing marine eutrophication requires evidence and understanding of all aspects of the definition. The level of understanding is increasing and the evidence base is improving to the extent that the relevant regulatory and advisory bodies (European Commission and OSPAR in north west Europe) can move from a simple sectoral measure approach to a more holistic approach based on ecological quality. There are still challenges to predict, using ecological models, and to incorporate changes that take place at a regional or global scale into our assessment and management regimes. The OSPAR Convention has a Strategy to Combat Eutrophication, which is helping to ensure co-operation and co-ordination of activities amongst Contracting Parties in the north-east Atlantic region. Progress has been made towards a comprehensive assessment of eutrophication status using a set of harmonised criteria. This should allow a clear view of cause and environmental disturbance as the basis for a clear direction for management action. This will have to be set into the overarching need for sustainable development which balances the requirements for environmental protection, with social progress, good use of natural resources and economic growth. I believe this will encourage us to develop solutions that work with the environment and people and have the characteristic of a high knowledge base.

CONSEQUENCES OF ANTHROPOGENIC EUTROPHICATION IN THE KASTELA BAY (ADRIATIC SEA)

Ivona Marasovic
Institute of Oceanography and Fisheries
Split,
Croatia
E-mail: marasovic@izor.hr

Kastela Bay is a semi-enclosed coastal bay in the Middle Adriatic, having a total volume of 1,4 km^3. It receives a great amount of untreated wastewaters, both domestic and industrial. The first data on the phytoplankton of Kastela Bay can be traced back to some seventy years ago. Systematic studies of phytoplankton and other biotic and abiotic parameters have been carried out since 1956. The first changes in the Bay, such as a gradual increase in primary production, in density of phytoplankton cells, changes of the seasonal cycle, and increase in chlorophyll a concentrations were observed at the end of the 1970s. The structure of phytoplankton community has been changed, and dinoflagellate species, rather than diatoms, have become dominant. At the beginning of 1980s, these changes have become rather serious, since minor or more severe red tides have occurred on several occasions, accompanied by the mortality of the marine organisms, from time-to-time. At the beginning of 1990s, the first shellfish toxicity (DSP) was recorded in the Bay.

NEW APPROACHES TO MEASUREMENT OF EUTROPHICATION

David K. Mills
CEFAS
Lowestoft Laboratory
Lowestoft NR33 0HT
UK
E-mail: d.k.mills@cefas.co.uk

Eutrophication is a natural process that may result in undesirable changes to marine ecosystems. Its definition in a scientific context has been based on some or all of increases in nutrient loading, chlorophyll concentration and primary production, and decreases in transparency. However, policy driven definitions include references to increased nutrient loads, increases in algal growth and shifts in the balance of organisms. These biological effects can be regarded as symptoms of eutrophication. This talk focuses upon detection of the symptoms of eutrophication with particular emphasis on the emergence of new technical solutions to problem of obtaining a representative marine data sets from which we may assess the eutrophic state of a body of water. Examples of the use of new and emerging sampling platforms that can form the basis of effective monitoring programmes will be given. High frequency temporal and spatial data sets of physical, chemical and biological observations obtained from data buoys and towed bodies will used to demonstrate the strengths that autonomous monitoring systems can bring to the detection of eutrophication. In addition, examples of new generation automated *in situ* instrumentation will be presented together with examples of relevant data sets. Finally a view of the potential for uptake of new high frequency data sets into ecosystem models to provide large-scale estimates of environmental state with respect to eutrophication will be described.

NUTRIENT LIMITATION AND PHYTOPLANKTON GROWTH: A HISTORICAL PERSPECTIVE

Eystein Paasche
Section for Marine Botany, Department of Biology
University of Oslo, Blindern,
0316 Oslo,
Norway
E-mail: e.paasche@bio.uio.no

The two decades from ca. 1960 to 1980 saw a number of methodological and conceptual breakthroughs regarding nutrient-growth relationships, leading to conclusions that form the basis for our present understanding. Improved nutrient analyses were essential for this entire development. On the methodological side, the formulation of semi-defined growth media opened an avenue for experimentation with cultures of true plankton algae. The introduction of quantitative expressions describing nutrient-limited growth laid the foundations for later modelling. This research was aided by the application of the chemostat to microalgal research. Use of mesocosms opened the way for realistic studies of plankton communities under controlled conditions. The introduction of the 15N isotope to measure nitrogen uptake in field studies allowed new insight into the nutritional basis of primary production. On the conceptual side, the proposal that coastal waters are generally nitrogen-limited shifted attention away, for a time, from other potentially limiting nutrients (silicon, phosphorus, iron). The distinction between new and regenerated production offshore proved important for an understanding of the nutrient supply to coastal waters as well. Pulse uptake of nutrients in response to nutrient patchiness was recognised as a mechanism allowing plankton algae to grow in a nutrient-poor environment. Associated with this was the identification of variable C:N:P ratios in cultured algal species, raising the possibility that nutrient status might be judged by elemental analysis of plankton samples. At the species level, the ideas of nutrient-driven succession and resource competition did much to stimulate laboratory and field experimentation. Examples of all this will be given in my presentation.

NUTRIENT BUDGETS FOR THE WESTERN WADDEN SEA

Catharina J.M. Philippart*, Gerhard C. Cadée, Wim van Raaphorst and Roel Riegman
Netherlands Institute for Sea Research,
P.O. Box 59, 1790
AB Den Burg (Texel),
The Netherlands
E-mail: katja@nioz.nl)

Variations in nutrient availability often effect phytoplankton dynamics, such as biomass, primary production and species composition. In the eutrophic Marsdiep, the westernmost tidal inlet of the Wadden Sea, phytoplankton biomass and production almost doubled at the end of the 1970s and remained high ever since. Furthermore, the phytoplankton community changed drastically both between 1976 and 1978 and again between 1987 and 1988. It was relatively stable in-between (1974–1976, 1978–1987) and hereafter (1988–1994). Compilation of phosphorus and nitrogen budgets (1974–1994) is applied to analyse which input or output factor is dominant in determining the variation in nutrient availability. Our results indicate that the N-budget of the area is not only correlated with nitrogen loading but also with the community structure of phytoplankton. The latter result suggests enhanced loss of nitrogen to the sediment through increased deposition of larger algal cells, i.e., an additional output of the nitrogen budget is determined by the phytoplankton community itself. Although phosphorus and nitrogen loading decreased since the mid-1980s, chlorophyll-a concentrations and primary production remained high until the present day. This unexpected observation is most probably due to compensating effects on the phytoplankton of a steady increase of silicate since the beginning of the 1990s, underlining the necessity to additionally compile silicon-budgets to fully understand phytoplankton dynamics in coastal waters.

THE EFFECTS OF REDUCED NUTRIENT LOADINGS IN DUTCH COASTAL WATERS

Theo Prins, L.P.M.J. Wetsteyn, J.C. Kromkamp, V. Escaravage
National Institute for Coastal and Marine Management / RIKZ
PO Box 8039
4330 EA Middelburg
The Netherlands
E-mail: t.prins@rikz.rws.minvenw.nl

Anthropogenic eutrophication is considered to be the cause of elevated phytoplankton concentrations, harmful algal blooms and, possibly, increased secondary production in Dutch coastal waters. The OSPAR policy, aiming at a 50% reduction of riverine N and P loadings, has been implemented successfully for phosphate, while nitrogen levels show only a slight decrease. Future reductions in nitrogen loading to Dutch coastal waters are expected, however. In order to be able to predict the changes in phytoplankton as a consequence of reduced nutrient loadings, several approaches have been taken. Mesocosm experiments, mimicking conditions in the Dutch coastal zone, were carried out to study the responses in phytoplankton biomass and production to various nutrient-loading scenarios. In a recent analysis, the Oosterschelde estuary (SW Netherlands) was used as a case study. This system has experienced a drastic reduction in freshwater input in the 1980s, as a consequence of engineering works, and provides an example of a system with a major reduction in nutrient loadings. As this estuary is important as a shellfish culture site, it has been argued that this reduction in nutrient loading has affected the carrying capacity for aquaculture. The developments in nutrient levels, phytoplankton concentrations and production, and the significance for shellfish culture will be discussed in relation to the decreased nutrient loadings.

MEASUREMENTS OF PRIMARY PRODUCTION IN KATTEGAT AND IN ADJACENT WATERS OF THE BALTIC ENTRANCE REGION: A BRIEF HISTORICAL REVIEW

Lars Rydberg.
Department of Oceanography, University of Gothenburg
Gothenburg,
Sweden
E-mail: lary@oce.gu.se

Measurements of primary production in Kattegat and in adjacent waters of the Baltic entrance region are presented. The presentation includes a brief review of long-term trends, but also of spatial and seasonal variability. Data are discussed in the light of changing and variable nutrient supply. Other mechanisms affecting primary production, such as mixed layer depth, changing ecology and hydrography are also considered. An interpretation of concepts such as net or regenerated production, in relation to the measured primary production, is given.

LONG TERM NUTRIENT TRENDS AND PHYTOPLANKTON RESPONSE IN DELAWARE ESTUARY, USA

Jonathan H. Sharp
Graduate College of Marine Studies
University of Delaware
Lewes DE 19958
USA
E-mail: jsharp@udel.edu

The Delaware Estuary receives one of the highest nutrient loadings per water volume of any nearshore aquatic environment in North America. Yet, curiously, this heavily urbanized, river-dominated estuary does not show many of the characteristics of eutrophication. Evaluation of consistent monitoring data sets shows very large changes in nutrient and dissolved oxygen concentrations and ratios over the past several decades and over the last century. Our own long-term sampling from the past two decades, supporting various research projects, allows linkage to the longer data sets and provides a better understanding of microbial (phytoplankton and bacterial) activity. Evaluation of dissolved oxygen data allows some indirect estimates of past history in microbial activity. Although, we have very little information about phytoplankton on an organism level, it is possible to infer some qualitative interpretations from the mass balance information. It appears that physical features and nutrient ratios in the estuary are more important in controlling eutrophication than are just nutrient loadings or concentrations.

MODELLING THE NORTH SEA: ESTIMATING REGIONAL AND CROSS-BOARDER EUTROPHICATION PROBLEMS, AND THE POTENTIAL EFFECTS OF MANAGEMENT ACTIONS

Morten Skogen, Einar Svendsen, Henrik Søiland
Institute of Marine Research,
PB. 1870 Nordnes
5817 Bergen,
Norway
E-mail: morten@imr.no; einar@imr.no; henrik@imr.no

An environmental status for year 2000 of the North Sea and Skagerrak has been done based on outputs from a biophysical model (NORWECOM). The model results suggests that in year 2000 the mean annual primary production in the North Sea was the highest in the period 1985–2000, and that the net inflow through the English Channel, due to an extreme strong influx in the fourth quarter, was the highest on an annual basis in the period 1955–2000. Also the oxygen levels and sedimentation rates in the North Sea and Skagerrak have been examined, and a eutrophication assessment conclude that, except for the winter values of nitrate, eutrophication is not a big problem in most of the Skagerrak and Kattegat area. The effects of reducing the nutrient inputs (either P or both P and N) by 50 % on the spatial distribution of flagellate production and the practical use of the model system to predict harmful algae distribution and decay are demonstrated

EUTROPHICATION AND ALTERED PHYTOPLANKTON BEHAVIOR: BIOMASS VERSUS SPECIES-BASED APPROACHES

Ted Smayda
Graduate School of Oceanography
University of Rhode Island
Kingston, RI 02881
USA
E-mail: tsmayda@gso.uri.edu

Subjective descriptions and, increasingly, mass balance approaches rooted in Redfield Ratio stoichiometry and dose-yield kinetics are usually applied to classify whether a coastal water body has become eutrophicated, and to characterize the degree of hypernutrification. From this information, water quality classification schemes have been formulated and used by regulatory agencies. The mass balance approach, which is more quantitative, is based on the interactions (relationships) that occur among plant nutrient elevation, seasonal oxygen deficiency, and increases (above long-term baseline levels) in phytoplankton biomass (usually as chlorophyll) and primary production. While powerful insights have been obtained, the linkages between altered phytoplankton behaviour and nutrient enrichment of coastal waters, and the trophic mechanisms involved, are unclear and controversial. As a result, the abatement procedures and guidelines issued by regulatory agencies are also tenuous. Inexact definition of what is a bloom; general failure to recognize that eutrophication is a process rather than a simple on/off event; disregard of species and functional group behaviour; inadequate ecophysiological extrapolations; experimental difficulties; related blooms in pristine and oligo-nutrified waters, and entrenched resistance to multiple factor regulation, demonstrated to occur, in favour of single factor and common cause theory (Liebigian) seriously compromise mass balance approaches. These issues and the need to incorporate species-specific and functional group ecophysiology in place of community biomass as the basis of the mass balance approach to quantify eutrophication and its effects will be addressed. In this, the characteristics and stages of eutrophication as a process will be described, along with the different ways in which nutrients regulate community structure, species distributions and bloom behaviour.

SCREENING BIOGEOCHEMICAL, AND ECOLOGICAL, MODELS OF ENRICHED MARINE COASTAL ECOSYSTEMS

Paul Tett
Dept. of Biological Sciences
Napier University
Merchiston Campus
10 Colinton Rd.,
Edinburgh EH10 5DT
UK
E-mail: p.tett@ichrachan.u-net.com

Eutrophication is defined by the EC as:

> 'enrichment of water by nutrients especially compounds of nitrogen and phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms and the quality of the water concerned.'

Implicit in the definition, the history of the concept, and the use of the word 'undesirable', is the idea that eutrophication is a process and that it is a matter of concern when this process results substantially from human actions and changes marine ecosystems from their 'natural' state. The definition may be broken down into 3 causally linked stages, all of which must occur for eutrophication to be recognised. Objective standards have been proposed for recognition of the first and second stages, but not as yet for stage 3. My aim in this talk is to consider the use of several types of model for diagnosing or predicting each stage in the autrophication process. I will show that stages 1 and 2 are relatively easy to deal with, whereas stage 3 is difficult: it is at the limit of our current ecological modelling capability. The models considered are: (1) a screening model based on the recommendations of the UK Comprehensive Studies Task Team, in which the key terms are bulk exchange rate and the yield of chlorophyll from nutrient; (2) a series of dynamic models of increasing complexity, culminating in the 2-microplankton model 2MMPD. Microplankton models jointly parameterise pelagic autotrophic and heterotrophic processes: i.e., they include microalgae, bacteria and protozoa in the same compartment. Mesozooplankton activity is represented by a grazing pressure applied from observed zooplankton abundance, often taken from CPR data. Results from 2MPPD are shown for the northern North Sea and the Firth of Clyde using different physical models. Results are shown from numerical experiments concerning the effect of changing N:Si ratios and of removing protozoan grazing.

VARIATIONS IN NUTRIENT RATIOS AND AQUATIC FOOD WEBS

R. E. Turner[1], Nancy N. Rabalais[2], Quay Dortch[2], Dubravko Justic[1]

[1]Coastal Ecology Institute, Louisiana State University, Baton Rouge, Louisiana, USA 70803; [2]Louisiana Universities Marine Consortium, 8124 Highway 56, Chauvin, Louisiana, USA 70344;
E-mail: euturne@lsu.edu; qdortch@mail1.lumcon.edu

The dissolved Si:dissolved inorganic nitrogen (DSi:DIN) atomic ratios of riverine and coastal waters have been declining in many areas of the world to near a DSi:DIN ratio of 1:1, primarily because of land use practices affecting nitrate concentrations. These changes will profoundly affect coastal food webs. Diatoms, for example, begin the algae-zooplankton-fish food web and have an intracellular DSi:DIN ratio of 1:1. Also, the regeneration of DSi and DIN in the worlds ocean is approximately 1:1. This led Redfield and others (e.g., Redfield 1934, 1958) to postulate the existence of stoichiometric and physiological limits to phytoplankton growth. Results from field and laboratory studies have suggested that the lack of silica relative to nitrogen can control phytoplankton community composition, and Elser *et al.* (1996) have shown how nutrient ratios (commonly discussed in terms of nitrogen:phosphorus ratios) constrain organism organization at the cellular, organismal and community level. If the minimal DSi:DIN proportion of 1:1 for diatoms is not met, then an alternative phytoplankton community composed of non-diatoms may be competitively enabled. Officer and Ryther (1980) argued that as the DSi:DIN ratio fell below 1:1, the fisheries web would re-form and be composed of less desirable species. It turns out to be a correct prediction for the Louisiana shelf near the Mississippi River delta. Thus important fisheries could be affected by the relative quantities of nutrients being loaded into the receiving waters.

IS PHYTOPLANKTON A USEFUL INDICATOR FOR WADDEN SEA EUTROPHICATION?

Justus van Beusekom
Alfred Wegener Institute for Polar and Marine Research
Wadden Sea Station Sylt
List/Sylt,
Germany
E-mail: jbeusekom@awi-bremerhaven.de

In co-operation with the Common Wadden Sea Secretariat a study was carried out to specify the trilateral Ecological Target "to achieve a Wadden Sea which can be regarded as a eutrophication non-problem Non-Problem area". The work was done in close co-operation with activities in the framework of the OSPAR Common Procedure through which the whole OSPAR Convention Area will be designated as either Non-Problem, Potential Problem or Problem Area with regard to eutrophication. The study consisted of the development of a conceptual model, the analysis of time series, a literature analysis of parameters with potential suitability as indicators of eutrophication and the application of suitable parameters to the Wadden Sea. In this talk an overview of the project will be given. Focus of the presentation will be the question whether phytoplankton is a useful indicator of Wadden Sea Eutrophication. It is suggested to base the assessment of the eutrophication status of the Wadden Sea on the autumn values of ammonium plus nitrite. Phytoplankton is less useful. Only in the Western Dutch Wadden Sea a relation between nutrient input and mean annual chlorophyll was found. A contrasting situation was observed in the North Frisian Wadden Sea, where temperature has a dominating influence on the annual cycle of phytoplankton biomass.

PHYTOPLANKTON BLOOMS IN THE WESTERN PART OF THE BLACK SEA IN THE 1990S

Violeta Velikova
Institute of Fishery and Aquaculture Varna,
National Center for Agrarian Sciences,
4, Primorski blvd,
P.O.Box 72,
Varna- 9000,
Bulgaria
E-mail: violetev@mail.varna.tehcno-link.com

For the Black Sea ecosystem, the phenomenon of progressive eutrophication has been evident since the early 1970s. It has significantly influenced the level of phytoplankton density, biomass, species composition, and seasonal and inter-annual variability of the algal community. In the period from1972–90, the frequent and prolonged phytoplankton blooms made the Black Sea a famous reference point for water quality deterioration. The phytoplankton community of the Western Black Sea shifted from a highly diverse system to a virtually eutrophic phytoplankton culture. The substantial increase in loadings of inorganic nitrogen and phosphorus and decrease in silicon loading, compared to the1960s, induced numerous monospecific blooms, non-traditional summer maxima in biomass, and an increase in number of prominent, non-diatom outbursts. Since the early 1990s, the persistent reports about the irreversibly degrading Black Sea have started to disappear. A large data set, reflecting the temporal and spatial variability of microalgae in the Western part of the Black Sea in the 1990s, allows us to compare the present-day functioning of the phytoplankton community with previous periods, and to conclude that there are some positive signs of easement. The phytoplankton community maintains the capacity to produce large biomass, but with decreasing tendency. There was>an increase in Si:P and Si:N molar ratios and concurrent increase in the diversity of mass species (mainly diatoms), but only a few of them generated exceptional outbursts with a density of more than 10 million cells per litre. The observed positive tendencies in eutrophication alleviation are related to the economic status of the adjoining countries and consequent reduction of eutrophication.

THE MOST LIMITING NUTRIENT (PHOSPHORUS) AND EUTROPHICATION IN THE PEARL RIVER ESTUARINE COASTAL WATERS

Kedong Yin[1,3] and Paul J. Harrison[2]

[1]Department of Biology; [2]AMCE (Atmospheric, Marine and Coastal Environment Program), Hong Kong University of Science and Technology, Kowloon, Hong Kong, [3]South China Institute of Oceanology, Chinese Academy of Science, Guangzhou, China

E-mail: harrison@ust.hk

The Pearl River in southern China is ranked the second largest in China and 13th largest in the world by discharge volume. Since 1980th the Pearl River delta has gone through rapid population increase and economic growth. Time series of monitoring data showed periodic peaks of chl a and NO_3 in summer in the estuarine coastal plume south of Hong Kong. Those peaks in chl a are relatively low (<20 µg l^{-1}), but NO_3 is relatively high (>20 µg l^{-1}). The time series showed no increasing trend in NO_3 and chl a over the past decade, although at present, NO3 from the Pearl River is very high, reaching 100 µM. Some historical data indicated that nitrogen loading in the coastal waters may have more than doubled since 1970. However, dissolved oxygen has not shown any decrease in the past few decades. Hypoxia appears to local and episodic, not region wide. A review of historical data revealed that PO_4 concentrations have remained relatively low, below 1 µM over the past few decades. Low phosphorus concentrations might have been responsible for controlling eutrophication conditions in spite of high nitrogen loading. It appears that the most limiting nutrient concept can be expanded to the estuarine coastal ecosystem in terms of eutrophication status including not only algal biomass, but also dissolved oxygen or even phytoplankton species composition. Other coastal seas in China will be discussed briefly in terms of current eutrophication status.

APPENDIX 4: COPY OF LETTER OF INVITATION TO PARTICIPATE IN WORKSHOP

CONTRASTING APPROACHES TO UNDERSTANDING EUTROPHICATION EFFECTS ON PHYTOPLANKTON

An ICES Workshop co-sponsored by:

National Institute for Coastal and Marine Management (RIKZ), The Netherlands;

CEFAS, Lowestoft Laboratory, Lowestoft, UK;

ICES Working Group on Phytoplankton Ecology (WGPE)

Funded by RIKZ and CEFAS.

Co-chair: Peter Bot, David Mills, Lars Edler, Ted Smayda

Dear [name of Plenary Lecturer, Invited Talker, or Discussant]

The ICES Working Group on Phytoplankton Ecology (WGPE) at its annual meeting, held in March 2001 in Bergen, Norway, recommended to ICES that a workshop be convened to consider the impacts of nutrient enrichment of coastal waters and inland seas on phytoplankton behaviour and accompanying trophic responses. The approaches taken to evaluate the effects of eutrophication on phytoplankton dynamics traditionally focus on biomass (usually chlorophyll) and primary production to the neglect of species succession and bloom responses, energy flow and food (prey) quality. The ICES WGPE identified this neglected aspect of nutrient loading effects on phytoplankton community behaviour, i.e., the organismal approach, as a topic of major relevance to the unresolved debate over the impacts of coastal eutrophication on phytoplankton processes.

ICES recently approved the convening of this Workshop, to be held on 11–13 March 2002, in den Haag, The Netherlands. The primary Workshop aim will be to evaluate the mass balance vs. organismic approaches to quantify phytoplankton responses to coastal nutrient enrichment. In this evaluation, observational and experimental studies, both field and laboratory, are of interest, including regional ecology, population dynamics, cellular nutrient physiology and modelling. Workshop objectives are as follows:

- to identify the range of responses of phytoplankton communities to nutrient enrichment,
- to evaluate the relative importance of cellular, population and community level responses to nutrient inputs, and
- to improve predictions of phytoplankton responses to nutrient inputs.

Plenary consensus of Workshop participants will be sought with regard to the current status of, and types of investigative studies needed to quantify eutrophication impacts on phytoplankton dynamics. The consensus arrived at will be formalized in a manuscript co-authored by Workshop participants for publication in Ambio, Marine Pollution Bulletin, or other journal. It will also be forwarded to ICES for its use. We are also exploring publication of the Workshop presentations in a peer reviewed journal.

Approximately 30 funded speakers are being invited (along with ICES WGPE members) and other selected individuals to participate in the Workshop. Participation will be by invitation only. Given the relevance of your research interests to Workshop objectives, we cordially invite your participation, and specifically to present a

[30–40 min Plenary Lecture on ---]
[20 min oral presentation on ----- within a session on Case Histories],
[to participate in discussions].

Should you prefer an alternate topic relevant to Workshop objectives, we would consider your suggestion.

In order to prepare for the workshop we would appreciate it if you would inform us of your intention to attend by December 18 at the latest. Further details of the Workshop venue will be provided to you as they become finalized in the near future.

Following the Workshop, the ICES Working Group on Phytoplankton Ecology will also have its annual meeting on 14–16 March in Den Haag. Workshop participants are welcome to join the meeting as observers. Due to budget limitations accommodation and subsistence costs are not provided to cover participation in the WGPE meeting.

We will cover the costs of accommodation for up to 5 nights to a maximum cost for bed and breakfast of 75 euros. This will allow participants to take advantage of cheaper air travel by staying for one Saturday night. We would encourage all participants to use this option in order to maximise the number of participants we can afford to fund. We will provide information on accommodation in due course. In addition we will provide lunch at the meeting provide a per diem of 25 euros to cover the cost of 4 evening meals. A workshop dinner will also be provided. There is no fee for attendance at the Workshop and the cost of lunch and a workshop dinner will be covered by the funders.

We look forward to your response, and hope that you will be able to attend. Please send your responses to Lars, Chair of the ICES WGPE.

Sincerely yours,

Ted Smayda: tsmayda@gso.uri.edu
Dave Mills: d.k.mills@cefas.co.uk
Lars Edler: lars.edler@smhi.se
Peter Bot: p.v.m.bot@rikz.rws.minvenw.nl

[Invitations were sent by e-mail primarily by Dr Smayda and Dr Mills. Dr Edler made follow up phone calls to Scandinavian invitees; formal invitations (above) were then sent by Dr Bot, whose office coordinated responses in preparing for logistical needs at meeting site]

APPENDIX 5: LIST OF WORKSHOP PARTICIPANTS

Baars, Martien
Netherlands Institute For Sea Research (NIOZ)
Postbus 59
1790 AB Den Burg
The Netherlands
Tel: +31 222 369511
E-mail: baars@nioz.nl

Colijn, Franciscus
FTZ Westküste
Hafentørn Max Planck str.
D-25761 Büsum 21502
Germany
Tel. +49 4834 604200; + 49 04152–871533
Fax +49 4834 604299
E-mail: colijn@ftz-west.uni-kiel.de; colijn@gkss.de

Baretta, Job
National Institute for Coastal and Marine Management / RIKZ
PO Box 20907
2500 EX The Hague
The Netherlands
Tel: +31 703114285
E-mail: j.w.baretta@rikz.rws.minvenw.nl

Bot, Peter
Rijksinstituut voor Kust en Zee (RIKZ)
Postbus 20907
2500 EX The Hague
The Netherlands
Tel: +31 703114220
E-mail: p.v.m.bot@rikz.rws.minvenw.nl

Brockmann, Uwe
Universität Hamburg
Institut für Biogeo- und Meereschemie
Martin-Luther-King-Platz 6
D-20146 Hamburg
Germany
Tel +49–40–42838–3989/5733; Fax +49–40–42838–5235
E-mail: brockmann@uni-hamburg.de

Cugier, Philippe
IFREMER/Centre de Brest
DEL-EC-BB
B.P. 70
29280 Plouzané,
France
Tel: 33 (0) 2–98–22–49–19; Fax: 33 (0)2–98–22–45–48
E-mail: pcugier@ifremer.fr

Dahl, Einar
Institute of Marine Research
Flödevigen Marine Biological Station
N-4817 His,
Norway
Tel +47 370 59040; Fax +47 370 59001
E-mail: einar.dahl@imr.no

Devlin, Michelle
CEFAS
Lowestoft Laboratory
Lowestoft NR33 OHT
UK
Tel: +44 1502 527715
E-mail: m.j.devlin@cefas.co.uk

Dortch, Quay
Louisiana Universities Marine Consortium
8124 Highway 56
Chauvin, Louisiana 70344
USA
Tel: +1 985–851–2821; Fax: +1 985–851–2874
E-mail: qdortch@mail1.lumcon.edu

Edler, Lars
SMHI
Doktorsg. 9D
SE-26252 Ängelholm
Sweden
Tel: + 46 431 80854; Fax: + 46 431 83167
E-mail: lars.edler@smhi.se

Elmgren, *Ragnar*
Department of Systems Ecology
Stockholm University
SE-106 91 Stockholm
Sweden
Tel: +46 8 164016; Fax: +46 8 158417
E-mail: ragnar.elmgren@ecology.su.se

Føyn, Lars
Institute of Marine Research
P.O. Box 1870 Nordnes
5817 Bergen
Norway
Tel: +47 55 238501; Fax: +47 55 238584
E-mail: lars@imr.no

Flynn, Kevin
School of Biological Sciences,
University of Wales Swansea,
Singleton Park,
Swansea SA2 8PP
UK
E-mail: k.j.flynn@swansea.ac.uk

Fukuyo, *Yasuwo*
Asian Natural Environmental Science Center
Univ. of Tokyo
Yayoi, Bunkyo-ku
Tokyo 113–8657
Japan
Tel +81 3 35841–2782, Fax +81 3 5841–8040
E-mail: ufukuyo@mail.ecc.u-tokyo.ac.jp

Gowen, Richard
DARD AESD
Newforge Lane
Belfast BT9 5PX
Northern Ireland
Tel 02890 255511
E-mail: richard.gowen@dardni.gov.uk

Harrison, Paul
AMCE (Atmospheric, Marine and Coastal Environment Program),
Hong Kong University of Science and Technology,
Kowloon,
Hong Kong
E-mail: harrison@ust.hk

Hesse, Karl
FTZ Westküste
Hafentörn
D-25746 Büsum,
Germany
Tel: +49 4834 604203; Fax: +49 4834 604299
E-mail: hesse@ftz-west.uni-kiel.de

Horstmann, Ulrich
Institute for Marine Research Kiel
Düsternbrookerweg 20
24105 Kiel
Germany
Tel: +49 431 600 4274
E-mail: uhorstmann@ifm.uni-kiel.de

Huisman, Jef
IBED, Faculteit der Natuurwetenschappen, Wiskunde en Informatica
Nieuwe Achtergracht 127
1018 WS Amsterdam
The Netherlands
Tel: +31 20 525 7085; Fax: +31 20 525 7064
E-mail: jef.huisman@science.uva.nl

Ignatiades, *Lydia*
Institute of Biology
National Centre for Scientific Research "Demokritos"
P.O. Box 60228
Aghia Paraskevi
Athens 15310
Greece
Tel. +301 065 03629, Fax +301 065 11727
E-mail: igna@mail.demokritos.gr

Imai, Ichiro
Laboratory of Marine Environmental Microbiology,
Division of Applied Biosciences,
Graduate School of Agriculture, Kyoto University
Kyoto 606–8502,
Japan
E-mail: imai1ro@kais.kyoto-u.ac.jp

Jak, Robbert
Dept. for Ecological Risk Studies, TNO Environment,
Energy and Process Innovation
P.O. Box 57
1780 AB Den Helder,
The Netherlands
Tel. +31 223 638814, Fax +31 223 630687
E-mail: r.jak@mep.tno.nl

Jickels, Tim
Laboratory for Global Marine and Atmospheric Chemistry
University of East Anglia
Norwich NR4 7TJ
UK
E-mail: t.jickells@uea.ac.uk

Justic, Dubravko
Coastal Ecology Institute, and
Department of Oceanography and Coastal Sciences
Louisiana State University
Baton Rouge, LA 70803,
USA
E-mail: djusti1@lsu.edu

Kim, Hak-Gyoon
Oceanography and Marine Environment
National Fisheries Research & Development Institute
Busan, 619-900,
Republic of Korea
E-mail: hgkim@nfrdi.re.kr

Lancelot, Kristiane
Université Libre de Bruxelles
Ecologie des Systémes Apostiques, CP 221
B-1050 Brussels,
Belgium
E-mail: lancelot@ulb.ac.be

Malcolm, Stephen
CEFAS
Lowestoft Laboratory
Pakefield Road
Lowestoft NR33 OHT
UK
E-mail: s.j.malcolm@cefas.co.uk

Marasovic, Ivona
Institute of Oceanography and Fisheries
21000 Split, I. Mestroviea 63
Croatia
E-mail: marasovic@izor.hr

Mills, David
CEFAS
Lowestoft Laboratory
Lowestoft NR33 0HT
UK
Tel: +44 1502 524253; Fax: +44 1502 513865
E-mail: d.k.mills@cefas.co.uk

Paasche, Eystein
Department of Biology, Section for Marine Botany
University of Oslo
P.O. Box 1069, Blindern,
N-0316 Oslo,
Norway
Tel +47 22 85 4532; Fax: 47–22 85 4438;
E-mail: e.paasche@bio.uio. no

Park, Richard
SEAA
Clearwater House, Riccarton,
Heriot-Watt University
Augenue North
Edinburgh EN 14AP,
UK
Tel: +44 131 273 7215
E-mail: richard.park@sepa.org.uk

Peperzak, *Louis*
National Institute for Coastal and Marine Management/RIKZ
P.O. Box 8039
NL 4330 EA Middelburg
The Netherlands
E-mail: l.peperzak@rikz.rws.minvenw.nl

Philippart, Katja
NIOZ
Department of Marine Ecology
Postbus 59
1790 AB Den Burg
The Netherlands
Tel: +31 222 369563; Fax: +31 222 319674
E-mail: katja@nioz.nl

Prins, Theo
National Institute for Coastal and Marine Management
P.O. Box 8039
4330 EA Middelburg,
The Netherlands
E-mail: t.prins@rikz.rws.minvenw.nl

Rey, Francisco
Institute of Marine Research
Postbox 1870 Nordnes
N-5817 Bergen
Norway
Tel: +47 55238499; Fax: +47 55238584
E-mail: francisco.rey@imr.no

Rydberg, Lars
Dept. of Oceanography
University of Gothenburg
Box 460,
SE 405 30 Göteborg
Sweden
Tel +46 31–773 2856; Fax: +46–31–7732888
E-mail: lary@oce.gu.se

Sharp, Jonathan
Graduate College of Marine Studies
University of Delaware
Lewes DE 19958
USA
E-mail: jsharp@udel.edu

Smayda, Ted
Graduate School of Oceanography
University of Rhode Island
Kingston, Rhode Island 02881
USA
Tel. +1 401 874 6171; Fax. +1 401 874 6682
E-mail: tsmayda@gso.uri.edu

Svendsen, Einar
Institute of Marine Research
Postboks 1870, Nordnes
5817 Bergen,
Norway
Tel: +47 55 23 84 58; Fax: +47 55 23 85 84
E-mail: einar.svendsen@imr.no

Tett, Paul
School of Life Sciences
Napier University, Merchiston Campus
10 Colinton Rd.,
Edinburgh EH10 5DT
UK
Tel +44 131 455 2350; Fax: +44 131 455 2291
E-mail: p.tett@ichrachan.u-net.com

Turner, Gene
Coastal Ecology Institute
Louisiana State University
Baton Rouge, Louisiana
USA 70803
E-mail: euturne@lsu.edu

Van Beusekom, Justus
Alfred Wegener Institute for Polar and Marine Research
Wadden Sea Station Sylt
List/Sylt, Hafenstr. 43, 25992 List
Germany
Tel: +49 4651 956150
E-mail:jbeusekom@awi-bremerhaven.de

Velikova, Violeta
Institute of Fishery and Aquaculture
National Center for Agrarian Sciences,
4, Primorski Blvd, P.O. Box 72,
Varna- 9000,
Bulgaria
E-mail: violetev@mail.varna.tehcno-link.com

Yin, *Kedong*
Department of Biology, Hong Kong University of Science and Technology, Kowloon, Hong Kong, and
South China Institute of Oceanology
Chinese Academy of Science
Guangzhou,
China
E-mail: kyin@ust.hk